

STRUCTURE OF THE 1977 FOREST FIRE OCCURRENCE
PREDICTION PROGRAM

BY

PETER H. KOURTZ

Forest Fire Research Institute
Canadian Forestry Service
240 Bank Street
Ottawa, Ontario
K1A 0H3

January 1977

STRUCTURE OF THE 1977 FOREST FIRE OCCURRENCE
PREDICTION PROGRAM

Objectives

The program will be run each day at the Maniwaki and Thunder Bay Fire Centers to predict the cause, number and general location of forest fires that can be expected to occur between the present time and the end of the current burning period (8 PM). Also, the program will have the ability to predict the fire occurrence situation for the following day. These predictions should be useful for determining the amount and location of aerial detection activity and the general preparedness level for initial attack.

The program should be run early in the morning (before 9 AM) to provide a fire forecast for the morning planning session. Later in the day, if weather or fire arrival conditions change from the expected, the program may be rerun to provide a revised forecast of the expected number of fires yet to occur between the current time and the end of the day. Any time after the noon indices have been calculated, the program may be used to forecast the number of fires expected tomorrow.

The program is intended to assist the fire center personnel in determining the day's likely fire load. In previous years

fire center personnel were asked for their estimates of fire occurrence before the computer results could be viewed. This year, the computer results will be presented to the decision makers to be used in conjunction with their estimates. The decision makers will be asked to subjectively rank the computer estimates according to their own opinion of the day's likely fire occurrence situation.

The program is designed for forecast fires under "summer" burning condition. It will significantly under predict the occurrence of early spring grass and litter fires.

General Structure of the Program

The program attempts to forecast the expected (average) number of lightning and people-caused fires that will occur from now to the end of the day in each weather station area within the fire region. To accomplish this the program requires:

- a) Historical (5-year) summaries of fire occurrence by cause, fire weather index class and weather station area.
- b) A data base containing this current year's weather data for all stations and general fire statistics associated with each of this year's fires.

- c) Current and forecasted noon weather indices for each weather station in the region.
- d) 8 AM lightning sensor counts from each weather station and a forecast of afternoon's lightning activity.
- e) Current day's detected fires by location, detection time and estimated cause.
- f) Current day's detection patrol activity, including weather station areas patrolled, times of patrols and fires detected.

The program will be run on the FFRI's PDP11-T34 mini computer in Ottawa. Each fire center will be connected to this machine via a dedicated line and a computer terminal such as the Bell "Vucom". Because the computer has the capability to share its resources with several users each user will appear to have complete control of the machine even though both fire centers may be running programs simultaneously.

The historical data summaries and current year's data base are stored on the computer's disk available for immediate access.

The user must enter the necessary data into the computer in the conversational mode. That is, the computer asks a question and the user must respond. The output is presented on the

terminal in the form of tables and maps. At the end of each morning session the user will be asked to state his (her) opinion as to the accuracy of the general fire forecast. This assessment, the computer prediction and the actual number of fires to occur are stored in a separate file for later evaluation.

A fire danger map which considers the combined influences of predicted fire occurrence, fire weather and potential fire damage for each weather station area will be optionally output at the end of the morning run. This map should indicate the potentially dangerous fire situations for the day. At the beginning of the fire season, fire center personnel will be asked to rank the relative values of each weather station area.

A grid of uniform sized cells will be overlaid on the region where each grid cell associated with the closest weather station. A prediction of the number of fires in each cell will be made available to a detection patrol routing algorithm. This should be useful in determining the number of patrols and their routes each day.

Historical Data Summaries

Two 3-dimensional tables, one for predicting people-caused fires and the other for predicting lightning-caused fires are required. For each table each weather-station-day over a five

season period will be classified into cells according to the following classes.

TABLE 1:

PEOPLE

FIRES

NOON

FFMC

CLASS

1	0-75
2	76-80
3	81-84
4	85-88
5	89-91
6	91+

TABLE 2:

LIGHTNING

FIRES

8 AM

LIGHTNING COUNTS

0-20
21-100
101-500
501-1000
1001+

NOON

DMC

1	0-14
2	15-29
3	30-49
4	50-71
5	72-97
6	98-129
7	130+

YESTERDAY

NOON'S DMC

0-14
15-29
30-49
50-71
72-97
98-129
130+

	<u>NOON DC</u>	<u>YESTERDAY'S DC</u>
1	0-60	0-60
2	61-140	61-140
3	141-200	141-200
4	201-300	201-300
5	301-400	301-400
6	401-500	401-500
7	501+	501+

The weather index and lightning data for each weather station-day will be categorized into specific cells in both 3-dimensional tables. The corresponding number of fires per 1000 square miles (based on the size of the weather station area) and the number of observation days will be cumulated in these cells. From these values, the average number of fires per cell-day, per 1000 square miles that occurred in the past can be estimated.

In addition, a regression will be run to estimate the expected number of fires for classes with none or few observations. When there are few historical observations in a cell the regression estimate of the average will be used. Both tables and corresponding regression means will be stored in the computer disk for quick access by the prediction program.

Current Years Data Base

A separate computer program will be available to both fire centers to calculate the current and forecasted or revised fire weather indices for each station. This program automatically will update the weather portion of the current year's data base. Another program will be available for entering fire information into the data base. With this program any number in the data base including the weather data can be changed. The fire section of the data base should be kept as current as possible.

The current year's data base will contain the following information:

- a) Region, year, month, day
- b) For each weather station:
 - 1) Station Code
 - 2) 8 AM lightning sensor count and rainfall
 - 3) Noon rainfall, temperature, relative humidity, wind speed and direction and visibility
 - 4) Current day's noon FFMC, ISI, DMC, DC, BUI, FWI (forecasted or actual)

- 5) Next noon's forecasted FFMC, ISI, DMC, DC, BUI, FWI.

c) For each fire (stored by ignition date):

- 1) Start month, day, hour
- 2) Cause
- 3) Grid location
- 4) Detection month, day, hour
- 5) Nearest weather station number

The information contained within the data base will be used each day by the prediction program and will be stored on disk in the FFRI computer. This information will be available for other uses throughout the season (i.e. for summaries of fire and weather statistics). In addition, the data will be in a suitable form for future data processing that will be necessary to improve the prediction system.

User Input

Once the user has signed onto the computer with his pass number he must type:

@ FIRES R*

(Here R is the symbol for the RETURN key) Immediately the following question will be asked.

DO YOU WISH TO UPDATE THE FIRE AND WEATHER DATA BASE?

If the answer is YES a special update program will be activated and the user will be given the opportunity to change or add to any item in the data base. If the answer is NO or when the update is completed the fire prediction program will start.

The first question asked will be:

IS THIS A FORECAST FOR TOMORROW?

The user must type either YES or NO or just R. If only the RETURN key is pressed the program will assume the forecast is for the current day. If NO is typed a forecast for the current day will be prepared. Tomorrow's forecasted noon indices must be present in the data base if a forecast is to be run.

If a forecast for the current day is required the question: IS THIS THE FIRST FORECAST FOR THE DAY? must be answered with a YES or equivalent R or NO.

If a forecast for the current day is required the machine will ask:

HAVE THERE BEEN ANY DETECTION FLIGHTS TODAY?

The user must answer YES or NO or R. A RETURN (only) will be equivalent to NO. An answer of YES to this will bring a response of: GIVE THE WX STATION AREAS AND TIME(S) OF PATROL(S) and then STATION - - HOUR - - (24 hour clock). More than one hour can be entered to represent more than one patrol over the station area. This line will be repeated until a 99 is received. Any fires detected by these patrols should have been logged into the data base before the beginning of the session. Any fires reported by the public must also be recorded in the data base before an update is run.

Next, the user will be asked to enter the burning period's forecasted lightning activity. The machine will ask: DO YOU EXPECT THUNDERSTORM ACTIVITY THIS BURNING PERIOD? A RETURN or a NO answer are equivalent. If the answer is YES the machine will ask: HOW EXTENSIVE ARE THESE STORMS LIKELY TO BE (GENERAL [1], WIDELY SCATTERED [2], OR SMALL AND ISOLATED [3])? One of the three numbers must be typed. Next will appear the following question: WHAT IS THE LIKELY SEVERITY OF THESE STORMS (SEVERE [1], MODERATE [2], OR LIGHT [3])? One of the three numbers must be typed followed by a RETURN.

At this point the computer will make the calculations necessary for the forecast and present the output on the terminal. The following questions will be asked at the end of the session: EVALUATE THE COMPUTER ESTIMATES OF PEOPLE AND LIGHTNING FIRES ACCORDING TO THE FOLLOWING CATEGORIES

- 1) MUCH TOO HIGH
- 2) TOO HIGH
- 3) SLIGHTLY HIGH
- 4) ABOUT RIGHT
- 5) SLIGHTLY LOW
- 6) TOO LOW
- 7) MUCH TOO LOW

PEOPLE FIRE FORECAST _____ R

LIGHTNING FIRE FORECAST _____ R

The user must type the number that corresponds to his answers for both causes. Next, the user must evaluate the correctness of the general location of the fire situation as forecasted by the

machine: STATE THE FIRE CENTER'S OPINION AS TO THE CORRECTNESS OF THE FIRE LOCATIONS GIVEN BY THE COMPUTER.

- 1) FORECASTING MOSTLY IN THE WRONG AREAS
- 2) AGREE WITH ABOUT 1/2 THE FORECAST
- 3) REASONABLE WITH SOME EXCEPTIONS
- 4) A REASONABLE FORECAST
- 5) DON'T KNOW

PEOPLE FIRE LOCATIONS _____

LIGHTNING FIRE LOCATIONS _____

INITIALS OF THE PERSON(S) MAKING THESE EVALUATIONS _ _ _ _

The location evaluation phase will not be asked for if the probability of one or more fires is less than 50 per cent. The evaluation will be asked for only after the first run for the current day. The program will not automatically shut off until these questions are answered. An alarm on the terminal will sound every five minutes until the answers are received. If the machine is shut off without the answers the user will have to get FFRI assistance before he (she) will be able to run the program again. The evaluation results will be stored in a special file along with information about how often and why the program was

used. These data will be used to identify weaknesses in the program and to evaluate its success.

Forecasting Method for PEOPLE Caused Fires

A) Long-Term Historical Pattern

Five years of historical fire and weather data for each weather station area will be merged and summarized into the two previously described 3-dimension tables. At the same time an estimate will be made of each weather station's relative people-caused fire occurrence for all weather index day types per 1000 square miles. This estimate will be relative to the average fire occurrence per 1000 square miles for all weather station areas. A historical estimate of people-caused fires for a specific weather-station-day can be found by determining the correct cell in the table (based on the current noon's fire weather indices) and by multiplying the average number of fires per observation day times the size of the weather station area and by the occurrence adjustment factor for that station.

Unfortunately, many of the cells in the historical table will have none or few observations. A regression surface will be fitted to the table cell means in an attempt to make short projections into the areas of the table either missing or lacking observations. Where a large number of observations are present, actual means will be used. But, where observations are lacking,

a combination of actual and regression means will be used according to the following scheme for a given cell:

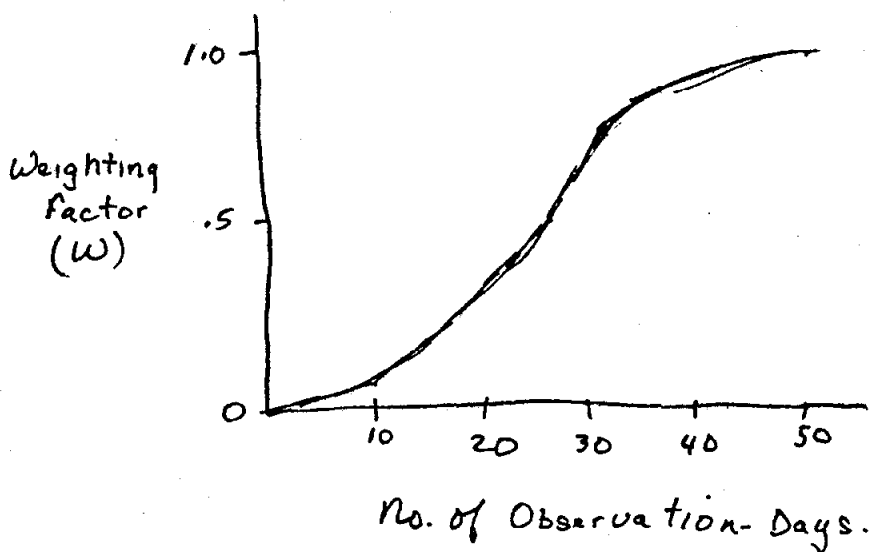
$$H_5 = W*O + (1.0-W)*R \text{ where}$$

H_5 = Historical estimated number of fires/1000 sq. mi.

O = Observed mean number of fires based on 5 years of observations

R = Regression mean

W = Weighting factor based on the number of observations-days in the cell according to the following graph:



No. of Observation-Days

B) New Trends in People-Caused Fire Forecasting

People-caused fire occurrence patterns can change abruptly from one year to the next. For example a new road can open up forest areas previously inaccessible. Past fires can influence wild berry crops and public use of previously unused areas. Seasonal weather trends can influence the amount of recreation use of the forest. Consequently, historical data should not be relied upon entirely, especially when new trends become obvious.

Each day, for each weather station fire and weather data are added to the current year's data base. Each time the program is run the computer will construct a current year's table of fire occurrence and observations for people and lightning-caused fires with similar classes as those used for the 5-year tables. For a specific weather-station day the fire occurrence mean of the current year's table will be used in conjunction with the corresponding 5-year historical mean to estimate the expected number of fires per 1000 square miles for the station of interest. As more observations during the current year in a particular cell are cumulated, more reliance will be placed on the average based on the current year's data rather than on the average based on the 5-years of data. The following equation gives the calculation procedure:

$H_6 = (1.0-W)H_5 + W*C$ where:

H_6 = Combined current and 5-year historical estimate of expected number of people-caused fires given the weather index situation.

C = The current year's average number of fires for the given weather situation. (W is the same observation curve used previously to determine the 5-year historical average (H_5) only based on the number of observations in this current year.)

C) Short Term Influence

In many cases where the general fuel moisture situation is similar, day after day, for a particular area, people-caused fire occurrence remains fairly constant. The rate of fire occurrence can significantly differ from the historical averages for many reasons. For example, a forest closure or non-representative weather readings can cause either a change in the average number of ignition sources or in the true state of the fuels. The 1977 version of the program attempts to identify and utilize these short term trends.

For a given weather station the previous three days' weather indices are examined. If the weather for either yesterday, yesterday and today and the day before, or the previous three

days were "similar" to today's weather the historical estimate of fire occurrence will be modified. Here "similarity" (S) is defined by the following equation:

$$S = ((x_1 - x_i)^2 + (y_1 - y_i)^2 + (z_1 - z_i)^2)^{\frac{1}{2}} \text{ where } x_i, y_i, \text{ and } z_i \text{ are the FPMC, DMC and DC class numbers for previous day } i \text{ (} i = 2, 3, 4 \text{).}$$

Previous day i is similar to the current day (day 1) if S is 2.0 or less. This scheme allows up to 2 indices to shift 1 class. If one or more indices shift 2 or more classes the weather will not be "similar".

The following equation will be used for each weather station area to consider the short term trends:

$$P_f = (1.0 - f) * H_o * WX + f * m \text{ where:}$$

P_f = Expected number of people fires

f = Weighting factor (see following table)

H_o = Historical average No. of fires expected

m = mean No. of fires in previous "similar" days

wx = weather station adjustment factor for area and occurrence rate.

The short term weighting factor (f) is determined according to the following table:

<u>Number of Previous Similar Days</u>	<u>Weighting Factor</u>
1	0.33
2	0.66
3	1.0

When the last three days are similar to today's, the historical average will be completely dropped in favour of the actual mean of number of fires for the last 3 days.

Lightning Fire Prediction

The number of lightning fires detectable in a given day is assumed to be the sum of a) those fires ignited by storms during the past 24 hours (8 AM to 8 AM), b) those fires started by storms more than 24 hours ago and c) those fires that will be started and detectable during the current burning period.

a) Lightning Fires Started During the Last 24-Hours

Each weather station will have a lightning counter that will be reset to 0 at 8 AM each morning. The 24-hour lightning count will be the basis of the prediction for the fires started during the last 24 hours. Because the counters have only a 20 mile range and because some weather stations are very widely spaced the sum of lightning counts at the station of interest plus the four nearest stations within 50 miles will be used as the criterion for thunderstorm activity. If this sum is less than 20 the program assumes that no 24-hour lightning fires are possible.

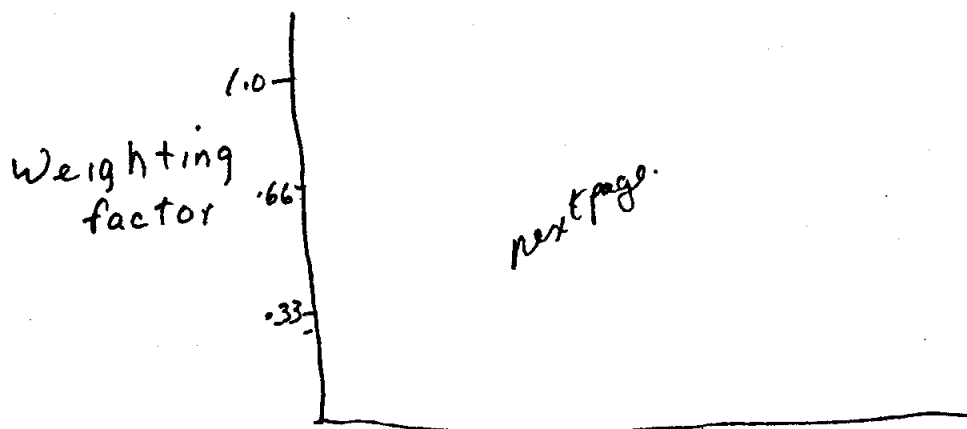
For days with lightning activity the count total and yesterday's DMC and DC indices for each station are categorized according to the previously described classes. The procedure used to calculate the number of lightning fires is identical to that used for people-fire prediction. A historical total and number of observations for each table cell using all weather stations based upon at least three years of observations will be set up based on the lightning count, yesterday's DMC and DC class data. Corresponding regression means for each cell in the table will be available. The combination of a cell's actual mean and regression mean will depend on the number of observations. The same weighting curve used for people fires will apply. These estimates will be on a per 1000 square mile basis.

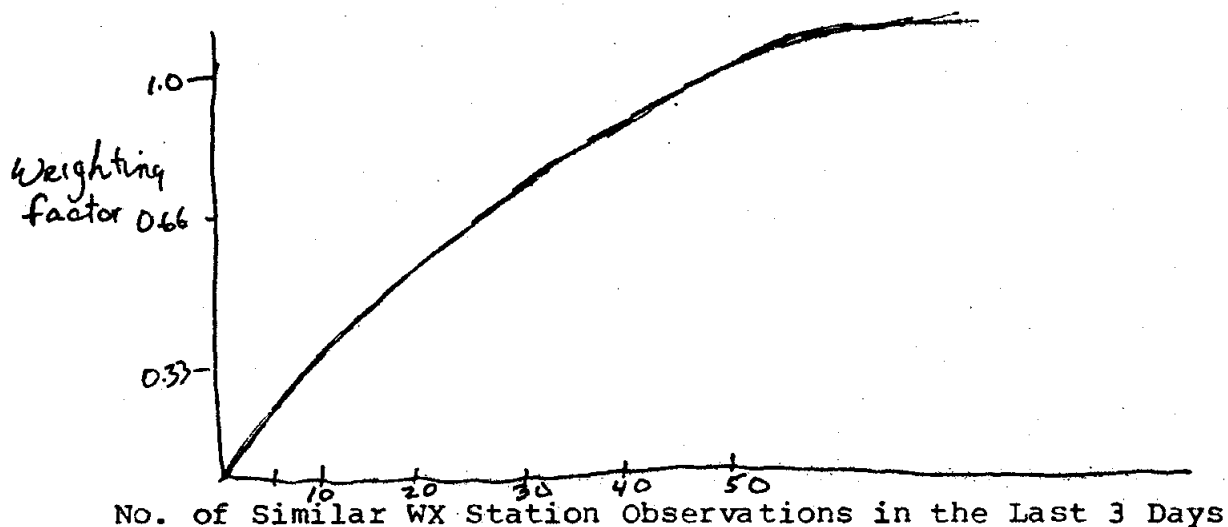
New trends in lightning occurrence will be handled in a similar manner to that described for people caused fires. The current year's total lightning fires and number of observation-

days per 1000 square miles using data from all weather stations in the current year's data base will be obtained for each weather station's lightning and index situation each run. The general weighting curve (used in the people-caused fire prediction procedure) will be used to combine the 5-year and current year's estimates of average fire occurrence.

Like the people-caused procedure, a procedure for identifying the most recent short-term trend in lightning fire occurrence will be incorporated into the prediction program.

For a given weather station's current lightning and index situation it is possible to identify in the data base all stations that had a "similar" situation during the previous three days. The weighting factor used for combining the actual average number of lightning fires of the past three days with the historical estimates depends upon the number of observations-days occurring in the past three days.





Once the final estimate of the average number of lightning fires per 1000 square miles is obtained for the station of interest it is multiplied by the appropriate area factor.

* Similarity here has the same definition as that used for people-caused fire prediction.

The lightning fire forecast procedure assumes that storms of equal intensity over two separate areas of similar fuel moisture states will start the same number of lightning fires. Zones of

high lightning fire occurrence are assumed to be caused by higher lightning occurrence or more favorable fuel moisture conditions.

b) Holdover Lightning Fires

Experience with fire forecasting during the past several years has confirmed the necessity of incorporating holdover lightning fires into the prediction. Here, a holdover fire is defined to be one started more than 24 hours ago (before 8 AM yesterday) and which becomes detectable today. The great difficulty in forecasting these fires is the lack of understanding of their behavior. Fewer than 25 per cent of all lightning fires fall into this category. This low number of observations and the great difficulty in estimating ignition times makes use of historical data nearly impossible. As an example of the problem in the data, suppose a holdover fire has been detected today. During the past week lightning storms have been reported at the nearest weather station almost every day. On which day did the fire start? To complicate this matter the quality of information in the fire reports can frequently be questioned. Often the fire reports are not completed for many days after the fire has been suppressed and often without proper consideration to the past weather. A common example of this is the numerous lightning fires claimed to have been started on day that had no lightning.

The holdover prediction procedure begins first by checking to see if the lightning counter data in the data base indicates a storm during the last four days at the weather station of interest. Here, the sum of the lightning counts at the four closest weather stations within 50 miles plus the counts at the station of interest are used. Storm activity is assumed for any day where this sum exceeds 20. If no storm activity is indicated for the past four days no holdover lightning fires are predicted.

For a given weather station on a day (in the last four) with storm activity the following information is assembled.

- a) The number of fires predicted for that storm based on the 24-hour-lightning fire forecast associated with that storm.
- b) The number of fires reported to the current time caused by the storm.
- c) An estimate of the intensity of aerial patrol activity over the weather station area since the storm. This can be classified according to the following table:

Holdover

Detection Adjustment Table

Storm	Number of	Weighting
-------	-----------	-----------

<u>Class</u>	<u>Patrols</u>	<u>Factor (Wp)</u>
1. Intensive	4+	1.0
2. Extensive	1-3	0.5
3. None	0	0

- d) Determine the current days buildup index for the station (from the data base) and classify it according to the following table.

Holdover Elapsed Time

<u>BUI Class</u>	<u>Factor (WBUI)</u>
0-20	0.25
21-60	0.50
61+	1.00

The number of holdover fires (L) for a given weather station area is found using the following equation:

$$L = H * WBUI * [Wp * A + (1 - Wp) * P] * \text{Area}$$

*Wp * A = Wx Stn area*

where - H is the per cent of holdover fires subjectively estimated to be detectable under the driest conditions for different elapsed times from ignition. (See table below.)

Holdover Elapsed Time Assumption

<u>Storm Time</u>	<u>Per Cent* Holdover (H)</u>
2 days ago	25
3 days ago	12
4 days ago	6

*Per cent of total fires started by the storm under the driest conditions.

-A is the actual number of fires started by the storm in the weather station area up to the current time.

-P is the original 24 hour predicted number of lightning fires for the storm in the weather station area.

AREA - area is 1,000 square miles for weather station area.

This method of predicting holdover fires attempts to overcome the lack of historical data by taking advantage of actual fire occurrence for the storm. Complications are introduced based on the amount of detection. For example, the day after a storm, suppose no detection was flown. The following day, however, detection patrols reported 3 fires. Would one or more of these fires have been detectable the day after the storm? We attempt to overcome this problem by considering detection intensity, the

original lightning fire forecast plus the actual number of fires reported.

c) Fires Started and Detected Within the Same Burning Period

Once again experience has indicated that these fires are very important -- especially in dry weather. We have no data on these fires since storm times are not recorded. The procedure used to forecast these assumes that the 24-hour lightning fire forecast based on only the historical 5-year and current year's data is a reasonable estimate of the number of detectable fires for that day. The discrepancy in the total number of fires for a storm and the assumption used in the lightning forecast procedures is at least partly explained by the fact that a large portion of the fires started by a storm self-extinguish. Although no data exists it would not be surprising to find that half the fires started by a storm self extinguish in the first 24 hours. Included in this group of fires are detectable fires on the day of the storm. It is common knowledge in the field that if detection patrols follow afternoon storms they will detect a large number of lightning fires -- many of which will be self extinguished by the time initial attack forces arrive.

The second difficult phase of predicting fires started by afternoon storms is the lack of thunderstorm forecasts. It will be up to the fire center personnel to assemble from the best

weather information available a forecast of the likely afternoon storm activity. The computer will ask the following questions:

- 1) ARE THUNDERSTORMS EXPECTED TO OCCUR DURING THE CURRENT DAY'S BURNING PERIOD? _____
- 2) HOW EXTENSIVE ARE THESE STORMS LIKELY TO BE (GENERAL [1], WIDELY SCATTERED [2], OR SMALL AND ISOLATED [3])? _____
- 3) WHAT IS THE LIKELY SEVERITY RATING OF THESE STORMS (SEVERE [1], MODERATE [2], OR LIGHT [3])? _____

The expected number of afternoon lightning fires is found using the following tables:

a) LIKELY EXTENT OF STORMS

<u>Class</u>	<u>Percent of WX Stations Assumed to be Affected</u>
General	75
Widely Scattered	40
Small and Isolated	15

b) STORM SEVERITY

Assumed

<u>Class</u>	<u>Lightning Count Class</u>
Severe	4
Moderate	3
Light	2

For all weather stations calculate the number of lightning fires using the 24-hour procedure without the short term learning feature. Use the current day's noon indices along with the forecasted lightning count class. Sum the lightning fire forecasts for each weather station area and multiply this by the likely extent factor. This total will be kept separate from the other estimates of lightning fires. No attempt will be made to say where these fires are likely to occur. Using the Poisson probability law and this total, a calculation of the probability of three or more such fires will be determined. If this value exceeds 50 per cent a special warning message will be printed.

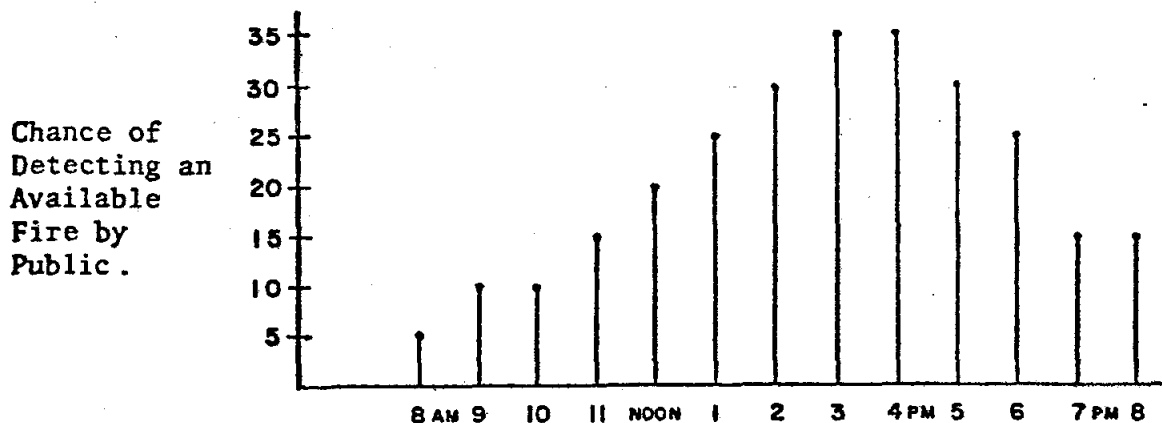
Mid-day Revisions of the Fire Forecast

The forecast program will have the ability to revise the original estimate anytime throughout the day. The revised forecast will be based upon:

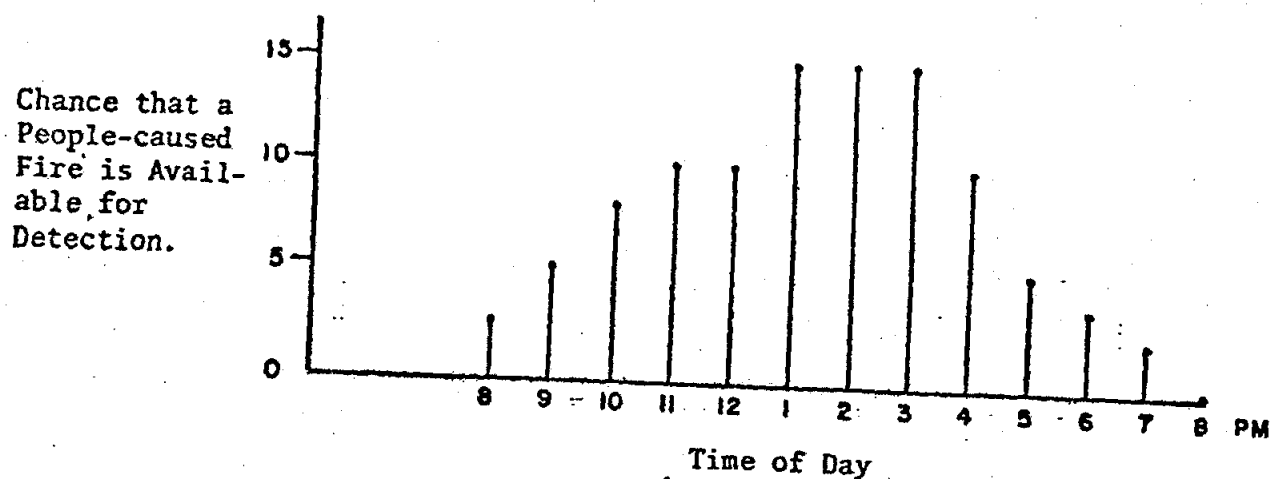
- a) the original forecast

- b) time of day
- c) air patrol activity
- d) public and aircraft fire reports.

A subjectively derived detection probability curve will be used to give the chance of detecting a fire at any hour of the day by the public. It is assumed that an air patrol is twice as effective in detecting an "available" fire, in a weather station area, compared to the public.



In addition, the procedure to revise the people-caused fire prediction requires an estimate of when a people-caused fire is likely to be "available" for detection throughout a typical day. The following subjective curve was derived:



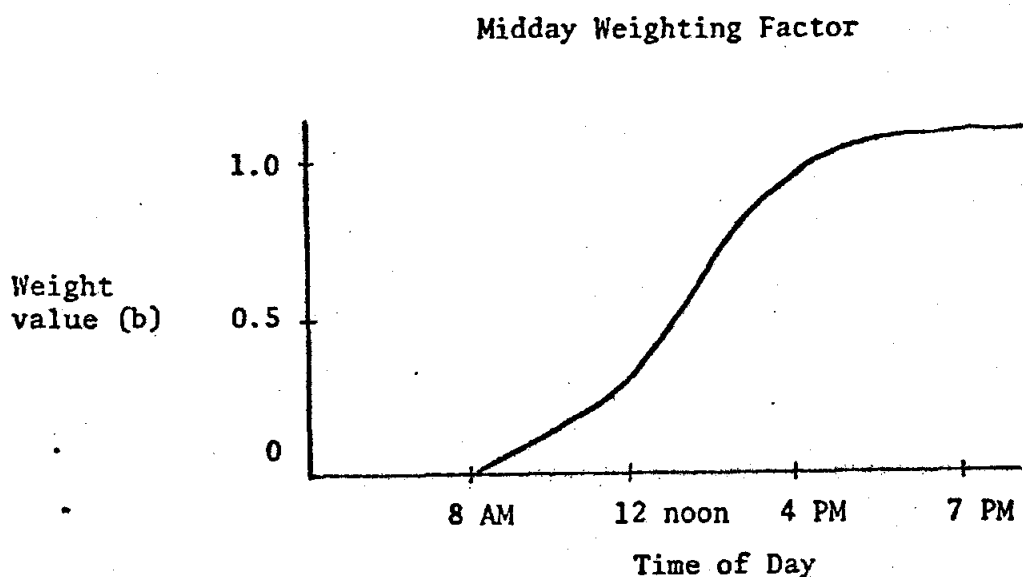
It can be shown that the number of fires detected up to time t divided by the cumulated probability of detecting a fire by time t , is a maximum likelihood estimate of the number of fires present, assuming a Poisson distribution of fire arrivals and a binomial detection probability law. However, this estimate is most "unstable" in view of the wide variance associated with the Poisson distribution and the low numbers of likely fire arrivals. Only as we approach the end of the day can we rely upon this estimate. Consequently, the system proposed will have the following form:

$$Y^1 = (1-b)* + b*Y \text{ where:}$$

Y^1 is the revised total fire occurrence estimate (Y)

Y is the maximum likelihood estimate of the total number of fires based on actual reports and detection probabilities.

b is a subjective weighting factor determined from the following graph:



The number of fires reported by the public and air patrols will be read into the system for each weather station area. At this time an estimate of the cause must be made. Also, the weather stations and times over which the air patrols flew, must be entered into the system. For a given weather station area, the probability of detecting a lightning fire up to time t is given as:

$$P(L) = \sum_{n=8}^t P(\text{avail}) (1.0 - (1.0 - Pd_n) (1.0 - Ad_n)^{x_n})$$

where $P(L)_t$ is the probability of detecting a lightning fire by time t .

Pd_n is the public detection probability at hour n

Ad_n is the aircraft detection probability at hour n per air patrol and x_n represents the total number of flights over the weather station during hour n ($Ad_n = 2(Pd_n)$).

$P_n(\text{avail})$ is the probability that a lightning fire is still available for detection at hour n .

$$P_n(\text{avail}) = P_{n-1}(\text{avail}) (1.0 - Pd_n) (1.0 - Ad_n)^{x_n} \text{ and } P_7 = 1.0.$$

This formulation assumes that all lightning fires are started before 8 AM and no new lightning fires are ignited throughout the current burning period.

The same equation can be used for finding the probability of detecting a people-caused fire ($P(p)_t$ by time t in a given weather station area and is:

$$P(p)_t = \sum_{n=8}^t P_n(\text{avail}) (1.0 - (1.0 - Pd_n) (1.0 - Ad_n)^{x_n})$$

where $P_n(\text{avail})$ is the probability of a people-caused fire still being available for detection during hour n

$$P_n(\text{avail}) = (P_{n-1}(\text{avail}) + N_n) (1.0 - P_{d_n}) (1.0 - A_d)^{x_n}$$

where N_n is the probability of the people-caused fire newly becoming available for detection hour n . (Taken from the previously described graph showing the chance that a people fire will become available each hour)

$$P_7(\text{avail}) = 0.0 \text{ (No people fires are available before 8 AM)}$$

The values of $P(L)_t$ and $P(p)_t$ are used in the calculation of the maximum likelihood number of lightning and people-caused fires (Y_L and Y_p) that should occur in a weather station area throughout the day.

$$Y_L = L_t / P(L)_t$$

$$\text{and } Y_p = P_t / P(p)_t$$

where L_t and P_t are the numbers of lightning and people-caused fires reported up to time t in the given weather station area.

The estimated number of lightning fires yet to occur between time t and the end of the day Y_L in the weather station area is:

$$Y^1_{Lt} = (1-P(L)_t) (1-b) Y_L + bY_L$$

where Y_L is the original early morning lightning fire forecast. Likewise, the expected remaining people-caused fires to occur between time t and the end of the day (Y^1_{pt}) in a weather station area is:

$$Y^1_{pt} = (1-P(p)_t) (1-b) Y_p + bY_p$$

This procedure ensures that as the end of the day approaches, the forecast relies more and more on actual experience and abandons the original forecast. But early in the day little faith is placed in actual results. Note that the typical situation will have no reported fires causing Y_L and Y_p to be 0.

Dynamic Danger Map

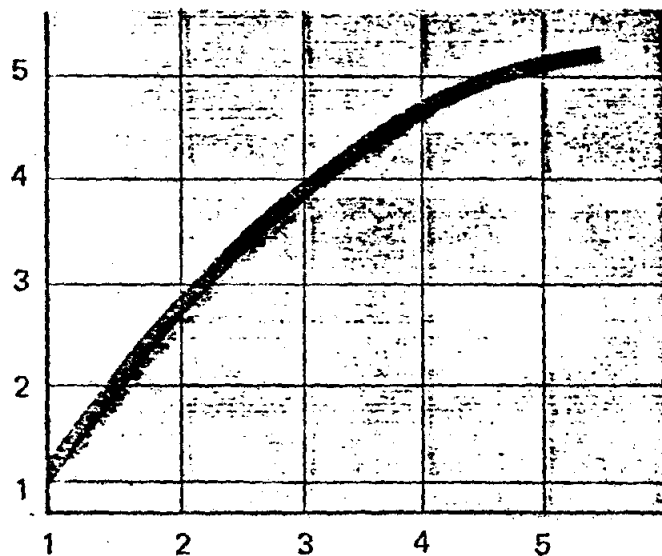
In addition to producing a fire occurrence forecast, a subjectively-derived fire danger map will be optionally produced. At the beginning of the fire season the fire center personnel will be asked to rate each weather station area from 1 to 5, representing the need or degree of "urgency" for early detection in that area. It will be assumed that a fire has just started in a random location and burning conditions are high. In making the urgency assignments, the fire control personnel will be asked to consider timber, recreation and political values, fuel conditions, potential damage and suppression costs, and attack

CRITERIA FOR URGENCY FOR DETECTION

- 1) On a cell basis — assign a number from 1 to 5 with 5 being in need of most (early) urgent detection.
- 2) Assume that one fire is burning (just started) in the cell in a random location.
- 3) Assume that the burning conditions (Fuel Moisture & wind) is HIGH.
- 4) In assessing "urgency" consider
 - i) values (timber, recreation, political),
 - ii) fuel condition,
 - iii) potential damage,
 - iv) potential suppression costs,
 - v) attack difficulty.
- 5) These numbers will be used to weight the forecasted numbers of fires in a cell in the following way:

Determination of Urgency Class Wt.

Urgency
Class as
Determined
by SCØ



Urgency Class Wt.

SCØ
Assigned
Classes

Weight for
Urgency

1
2
3
4

1
1.5
2
3
5

difficulty. The fire danger in a weather station area is defined as follows:

$$\begin{array}{ccccccc} \text{Fire} & & \text{Number of} & & \text{Urgency} & & \text{Fuel Moisture} \\ \text{Danger} & = & \text{Predicted} & \times & \text{Rating} & \times & \text{Rating} \\ & & \text{Fires} & & & & \end{array}$$

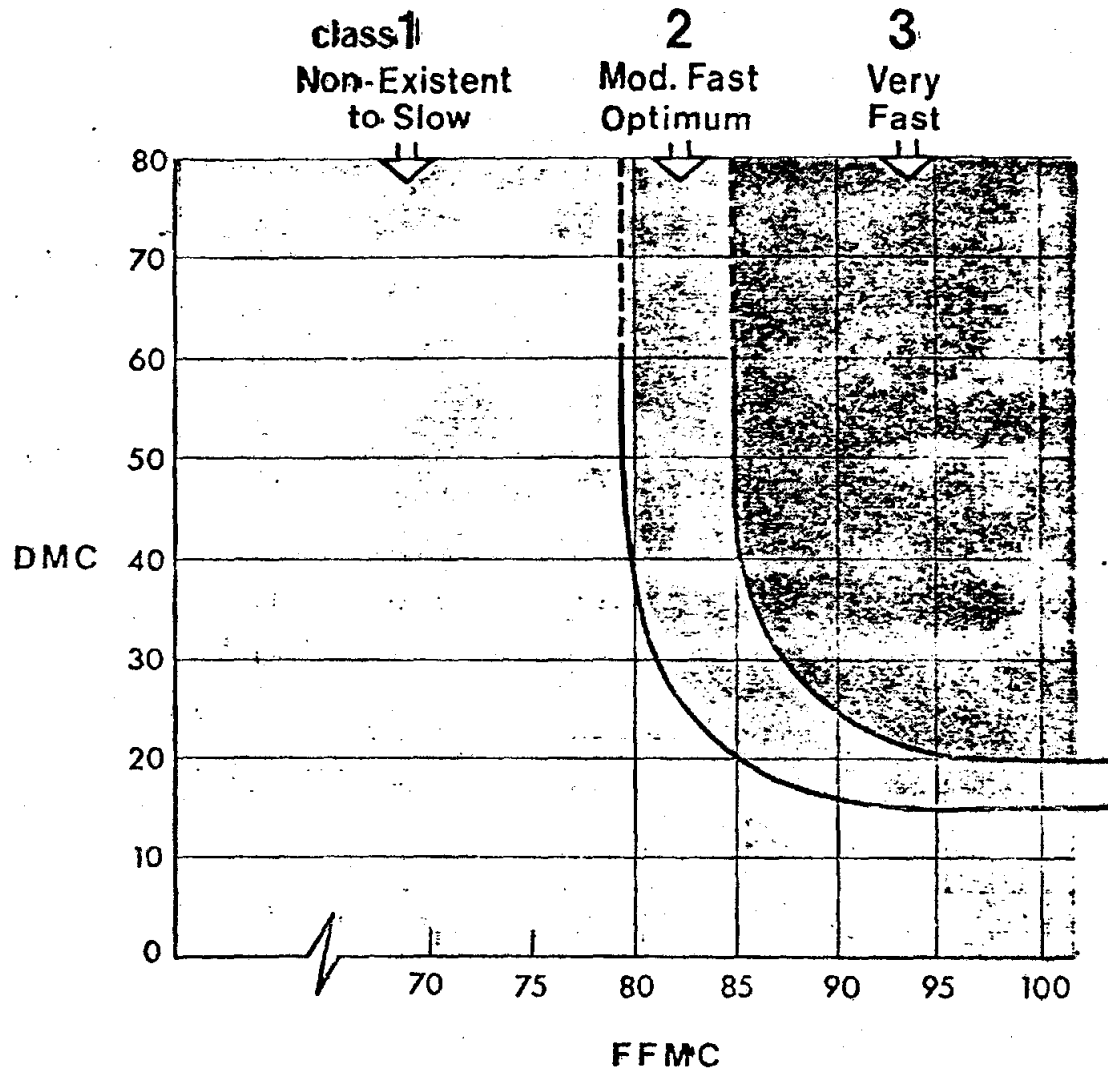
The fuel moisture rating is a number from 1 to 5 that represents the speed at which a fire was likely to spread. The number is determined from the following table:

This procedure assigns a weighting value from 1 to 25 to each fire predicted for weather station area. A high "urgency" area

Determination of Fuel Moisture Weighting Values

SPREAD CLASS (Slope 0-15%)

(J.S. Muraro)



Rate of Spread
Class

Weighting
Factor

1

1

2

2.5

3

5.0

with dry fuels received a high weighting for each predicted fire. The danger rating for even a high "urgency" rated area was low if either no fires were predicted or the fuels were wet. Danger values for each area are classified into four categories before they are printed in map form.

Output

The expected number and chance of 1 or more people-caused, 24-hour lightning and holdover lightning-caused fires will be printed for each weather station area. Totals for all weather stations for people, 24-hour lightning, holdover, and afternoon lightning fires will be separately printed along with the grand total.

The fire region will be divided into square grid cells, each of about 500 square miles in area. Each such cell will be associated with a nearest weather station. A total number of fires will be forecast for each cell based on the people and lightning fire forecasts for the weather station. The number of people-caused fires forecast in a cell at a specific time will be based upon Simard's diurnal people-fire occurrence curves. This grid will be used by another computer program for determining the best aerial patrol routes. It will be printed out in the form of a map if the user requests it.

File Structure

The program will use the following files:

1. MASTA.DAT containing:
 - REGION
 - YEAR
 - DAY
 - WX STN ID
 - 8 AM RAIN
 - NOON RAIN
 - TEMPERATURE
 - REPEATED FOR EACH
 - WEATHER STATION IN
 - REGION
 - RH
 - WIND DIR
 - WIND VEL
 - VISIBILITY
 - LIGHTNING COUNTS
 - FFMC
 - DMC
 - DC
 - ISI
 - ADMC
 - FWI

This file will have space for up to 40 days of observations. Periodically it will be transferred to tape for historical record purposes.

2. FORMET.DAT

This file will contain next noon's forecasted weather and index data for each weather station. Successive forecasts will not be stored -- only the last forecast. Its format will be identical to that of MASTA.

For files MASTA and FORMET the fire weather prediction program will enter data automatically. Program UPDATE will allow the user to list and change any number in these files. The actual formats will vary with region because of the varying number of weather stations.

3. FIRES.DAT containing:
- REGION
 - YEAR
 - MONTH starting
 - DAY time
 - HOUR
 - WEATHER STATION NO. (nearest)
 - CAUSE
 - GRID LOCATION
 - MONTH
 - DAY detection time
 - HOUR

This file contains information on each fire that occurred in the region to date. It must have the storage capability for up to 800 fires. The actual format will be a function of the region's requirements (i.e. fire location grid scheme). It

can be listed, revised or updated using program UPDATE. For
cause use the following categories: PEOPLE, HOLDOVER, LTG,
24-HOUR LTG, MID-DAY LTG.

4. HISTORY.DAT

The contents of this file will be:

	<u>Size</u> (numbers)
No. of lightning fires observed/1000 sq. mi.	245
No. of lightning observation days/1000 sq. mi.	245
Regression means/1000 sq. mi.	245
No. of people-caused fires observed.1000 sq. mi.	294
No. of people observation days/1000 sq. mi.	294
Regression means/1000 sq. mi.	294

The size of these tables is a function of the number of index
classes used.

RECORD.DAT

This file contains a record of the results of each run of the
prediction program. It will be written at the end of each
run. Data will cumulate for the whole season. Room for 500
records should be made. Each record will contain the
following:

Record Number
 Region
 A - Year
 Month
 Day
 Hour (First of day, mid--day revision
 Forecast Type or forecast for tomorrow)

Thunderstorm extent forecast
 Thunderstorm severity forecast
 Actual No. of holdover fires detected
 No. of holdover fires predicted
 Actual No. of 24-hour lightning fires
 B - 24 hour prediction of lightning fires
 No. of mid-day lightning fires
 No. of predicted mid-day lightning fires
 Poisson confidence limits for mid-day forecast
 Actual people fires
 Forecasted people fires

Total No. of people fires forecast
 Poisson confidence limits
 C - Actual No. occurring
 Subjective ranking of prediction
 Subjective ranking of forecasted locations

Total number of lightning fires forecast

Poisson confidence limits

Actual No. occurring

Subjective ranking of prediction

Subjective ranking of forecasted locations

Initials of person making subjective rankings

Section A of this file will be written with each successful run of the prediction program. Section B and C will be written for each 8 AM run of the prediction program. The data in section B and C refers to the total region and not to individual weather stations. A separate computer program called FIXER will be used to add the actual number of fires to RECORD for any day.

6. HOLDOVER.DAT

This file stores the air patrol frequency over each weather station area each day. These data are used in predicting the number of holdover fires.

The contents of the file will be:

Region, month, day and for each weather station the frequency of coverage that day.

A special program (FLIGHTS) is available to keep this file updated.

All these files will be READ ONLY protected so that the standard editing features will not function. Further protection can be added by "slaving" the user terminal so that only input and output associated with a specific job can be entered or displayed on the terminal.